Ionizing Radiation Detection for Exploratory Experiments in Low-Energy Nuclear Reactions

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LENR: University of Michigan (Cat B)

NUCLEAR ENGINEERING & RADIOLOGICAL SCIENCES
UNIVERSITY OF MICHIGAN

Project Title:
Ionizing Radiation Detection for Exploratory Experiments in Low-Energy Nuclear Reactions

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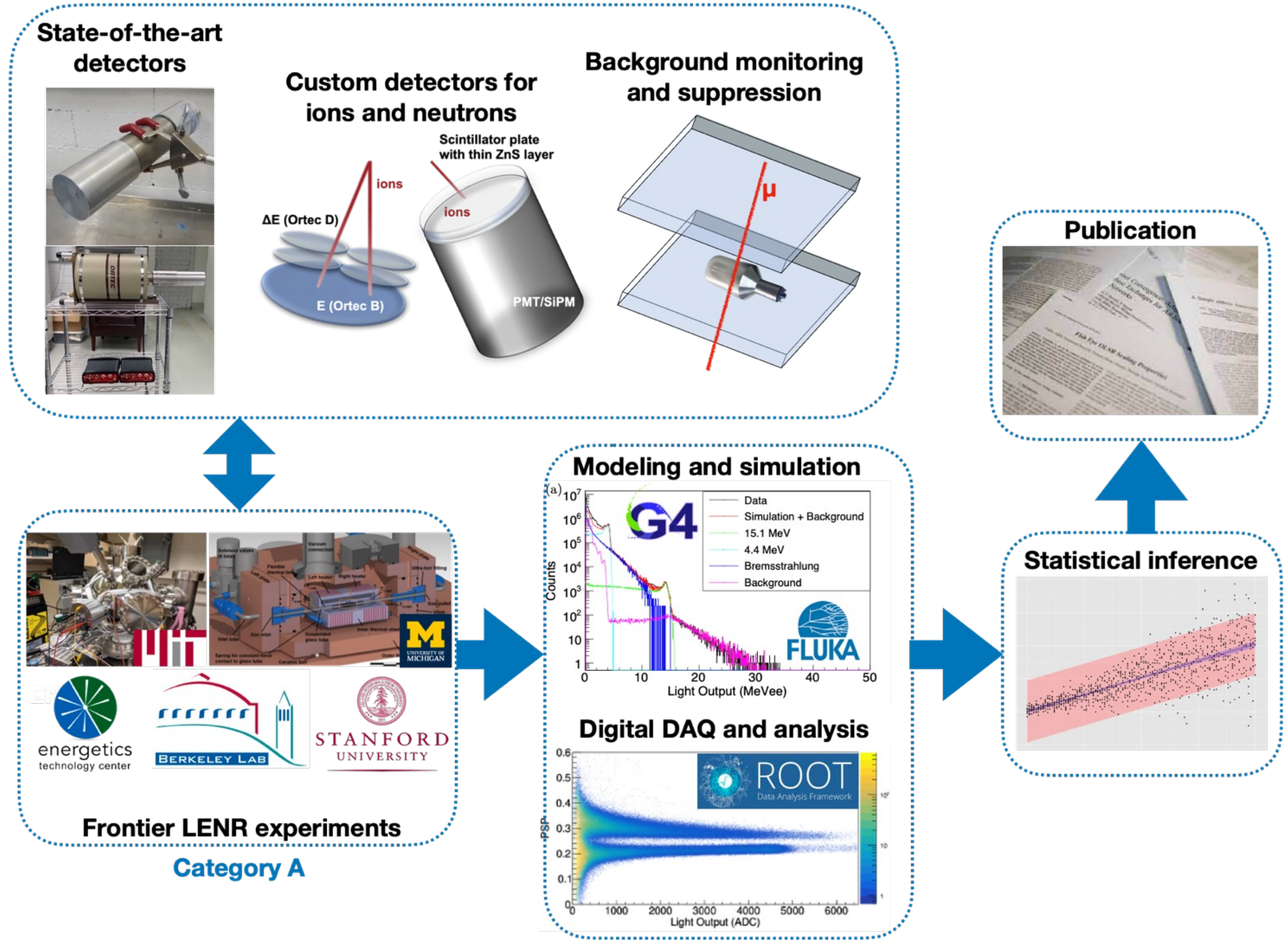
Project Outcomes:
Remove the tension between the practices and claims of the LENR and the mainstream nuclear physics communities



Key takeaway: Independent measurement of hypothesized radiation emission from LENR

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Goals, Innovation and Impact

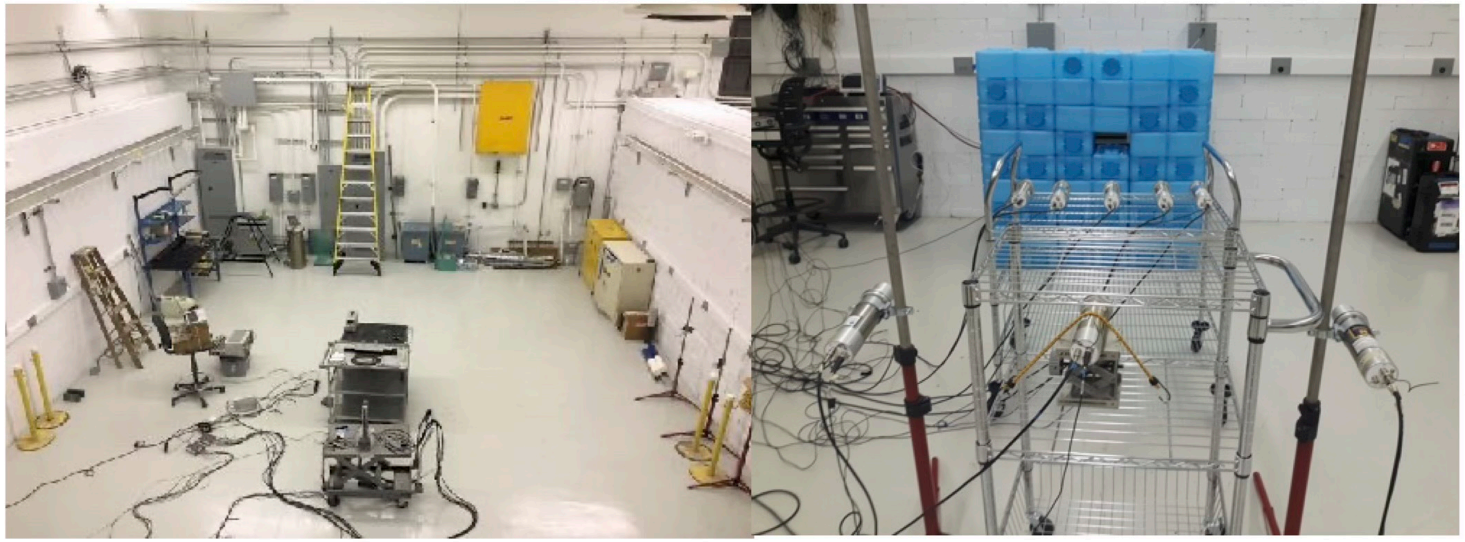
- Goal: support an evaluation of multiple hypothesis-driven LENR experiments by detecting ionizing radiation products

- Innovation:
  - independence of tools and methods from Category A experiments
  - adherence to established scientific practices in measuring and modeling ionizing radiation interaction with matter
  - separation of the personnel from Category A projects

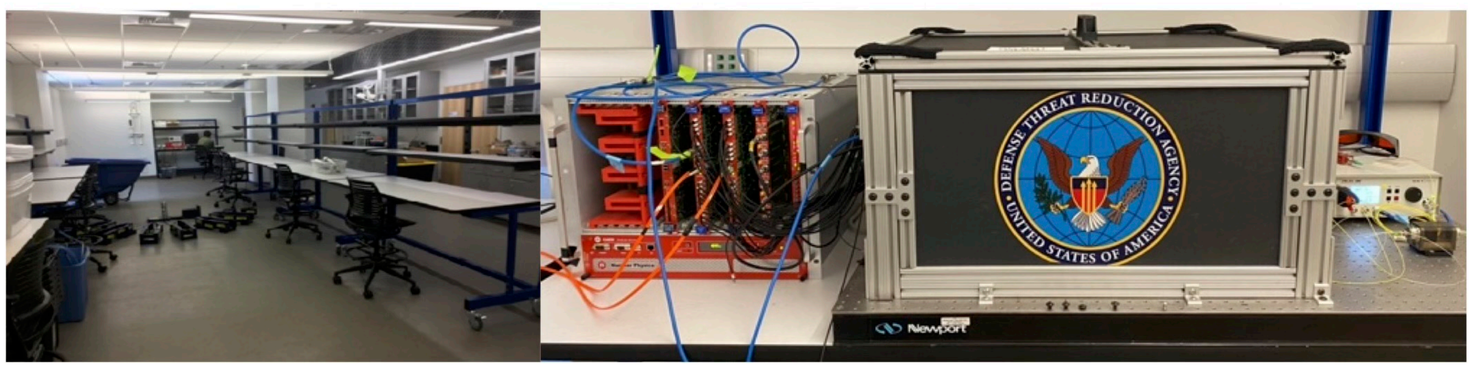
- Impact:
  - establish strict standards in evaluating hypothetical LENR signatures
  - help determine how research support should be directed to improve scientific understanding of LENR

Facilities

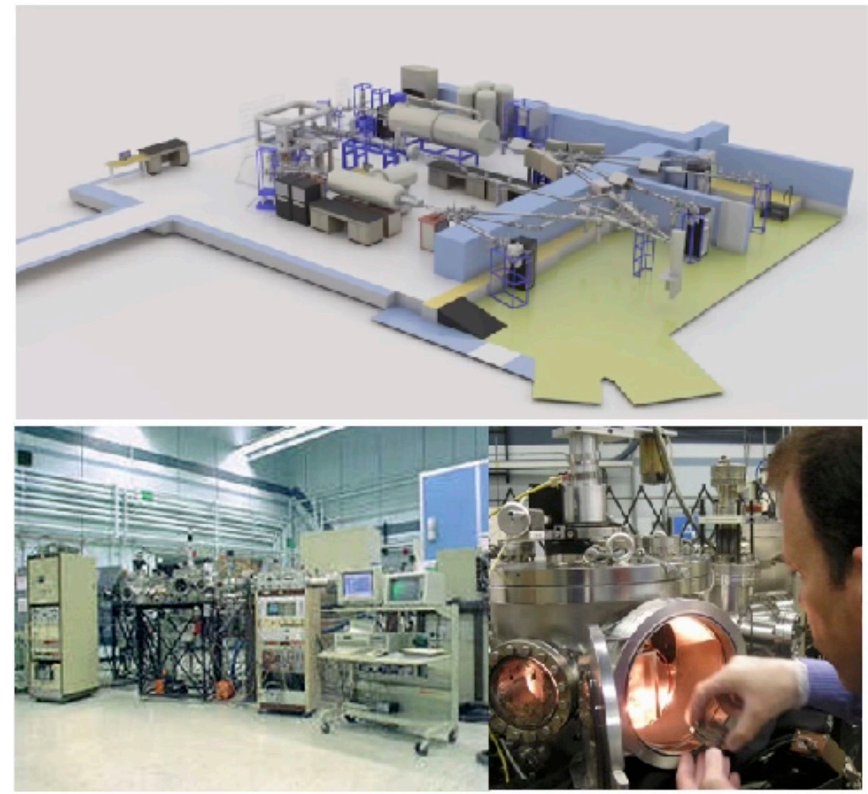
Neutron Science Laboratory



Applied Nuclear Science Instrumentation Laboratory



Michigan Ion Beam Laboratory



Standard Radiation Detectors Available for Cat A Experiments

Detector type	Particle type	Resolution			Rate*	Sensitivity	Threshold	Particle ID
		Temporal	Spatial	Energy				
CURRENTLY AVAILABLE								
Organic scintillators	FN	2 ns	≥2.5 cm	20%	50 kHz	30%	>50 keVee	Yes
Deuterated scintillator	FN	2 ns	5 cm	20%	50 kHz	30%	100 keVee	Yes
^{4}He	FN	75 ns	5 cm	20%	50 kHz	10%	50 keVee	Yes
Composite scintillators	FN, SN	2 ns	≥2.5 cm	20%	20 kHz	5–20%	50 keVee	Yes
CLYC	FN, SN, G	2 ns	3.8 cm	<7%	5 kHz	20%	10 keV	Yes
BF_3 / boron coated	SN	10 µs	2.5 cm	N/A	1 kHz	30%	0	Yes
$LaBr_3$	G	2 ns	5 cm	<3%	50 kHz	30%	10 keV	No
NaI(Tl)	G	2 ns	≥5 cm	6–10%	10 kHz	60%	10 keV	No
HPGe	G	10 ns	≥1 cm	<0.5%	10 kHz	40%	10 keV	No

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Custom Radiation Detectors Planned for Cat A Experiments

Detector type	Particle type	Resolution			Rate*	Sensitivity	Threshold	Particle ID
		Temporal	Spatial	Energy				
CONSTRUCTED FOR THIS PROJECT								
ΔE/E telescope	I	10 ns	0.8 cm	20 keV	10 kHz	100%	1 MeV	Yes
Muon veto	M	2 ns	≥ 50 cm	N/A	50 kHz	100%	5 MeV	No
Large B-doped organic scintillator	FN, SN	2 ns	≥10 cm	10–20%	50 kHz	60%	100 keVee	Yes

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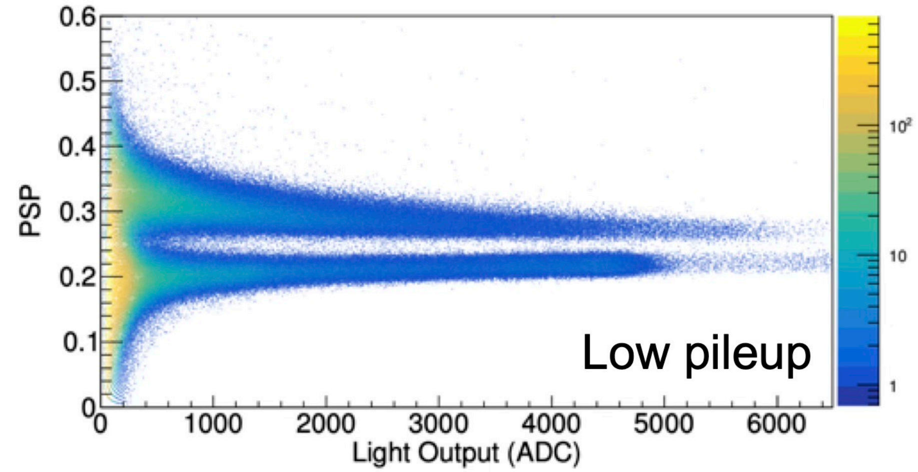
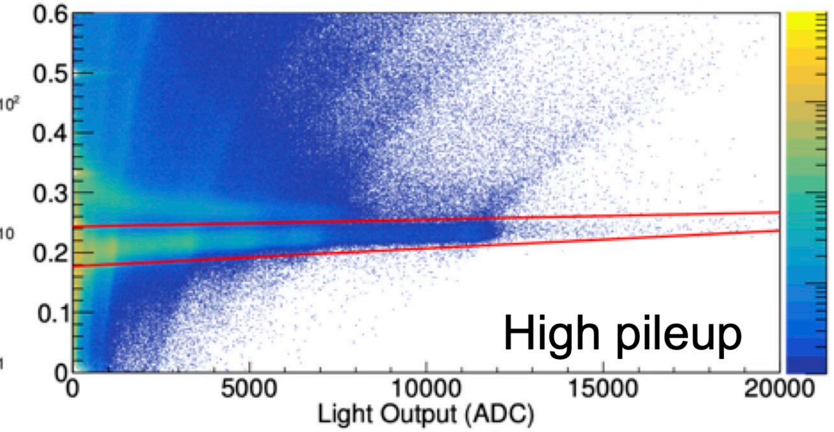
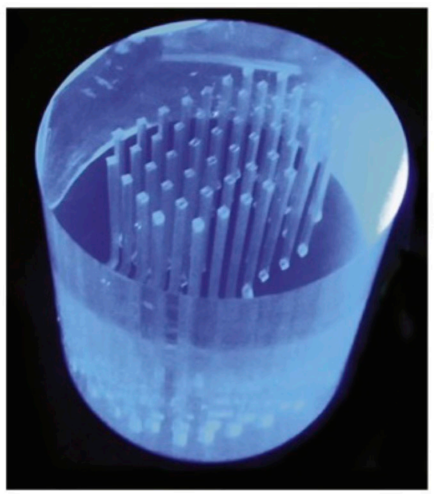
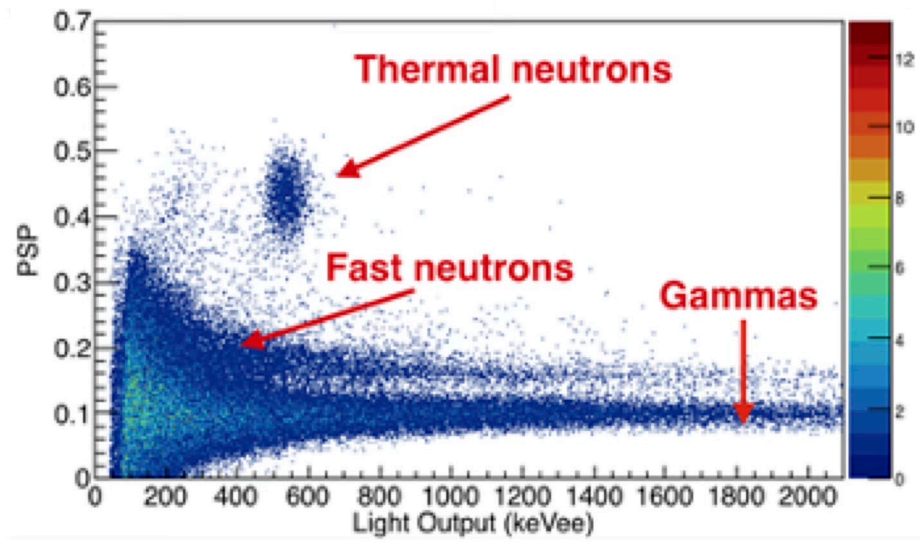
Neutron Detectors

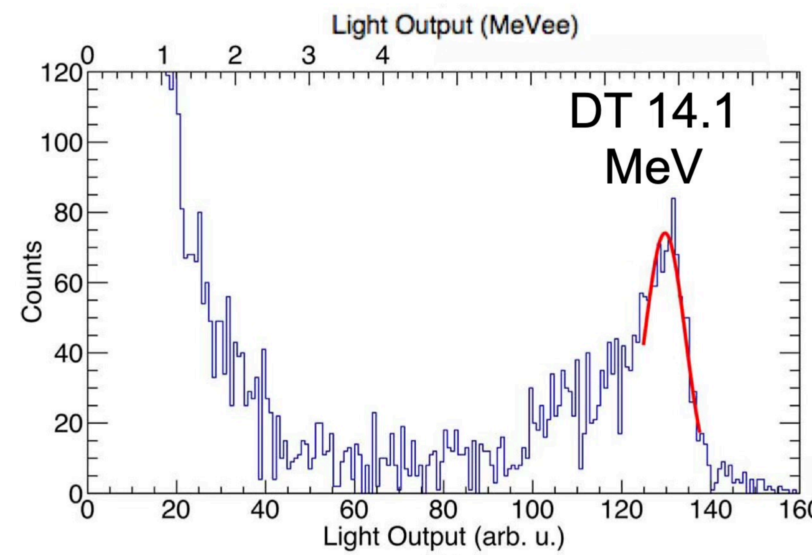
- Fast neutrons detected through nuclear recoil or thermalization + capture





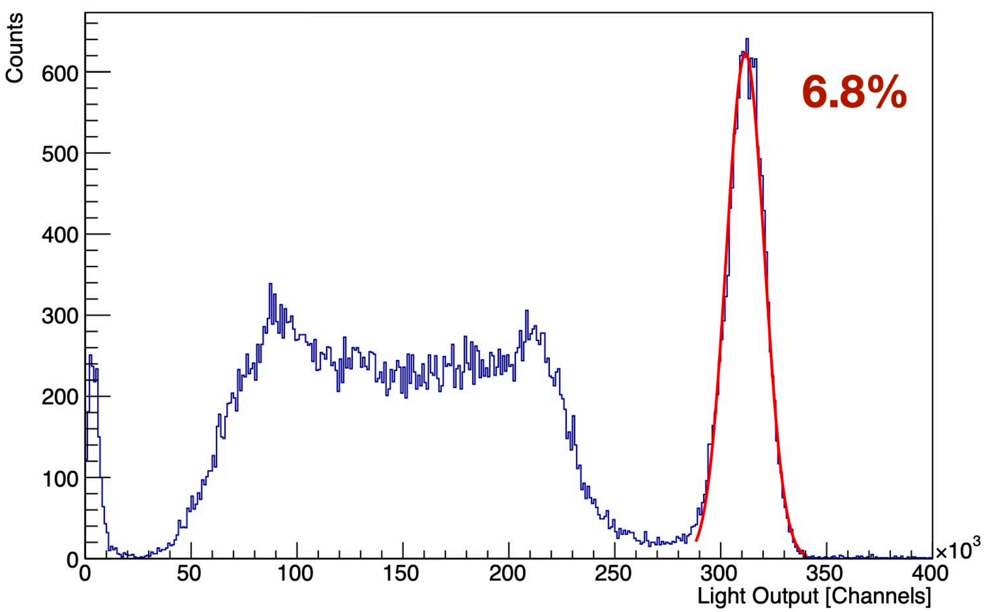




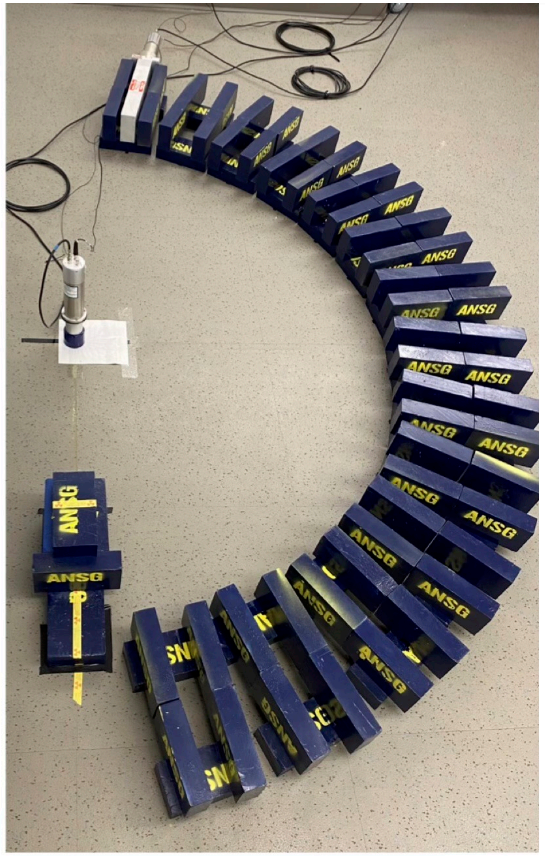


Gamma-Ray, X-ray, and Electron Detectors

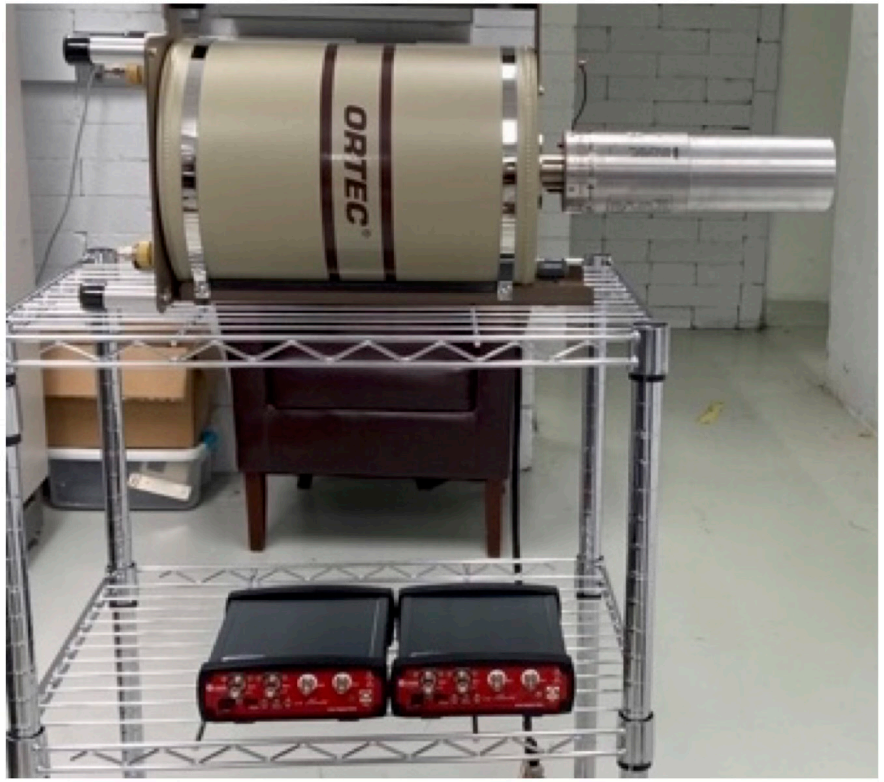
- CLYC (tri-mode), $LaBr_3$, NaI(Tl), HPGe



CLYC with digital DAQ



Large NaI(Tl) array



Transportable HPGe
with digital DAQ

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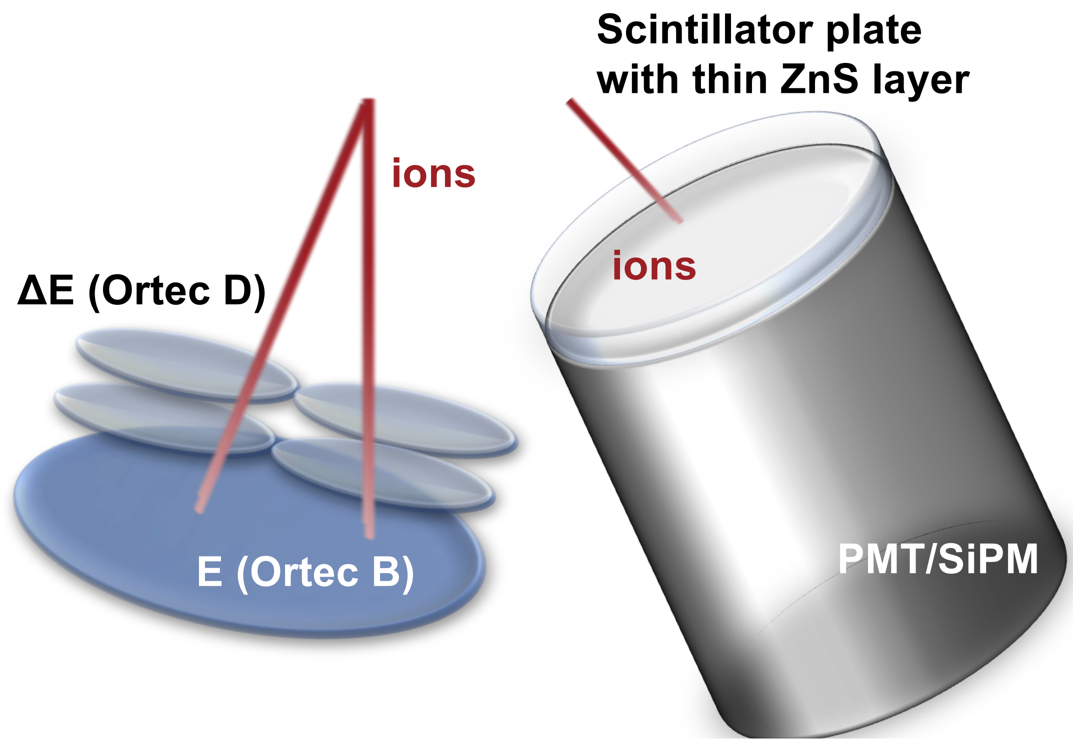
Ion Detectors

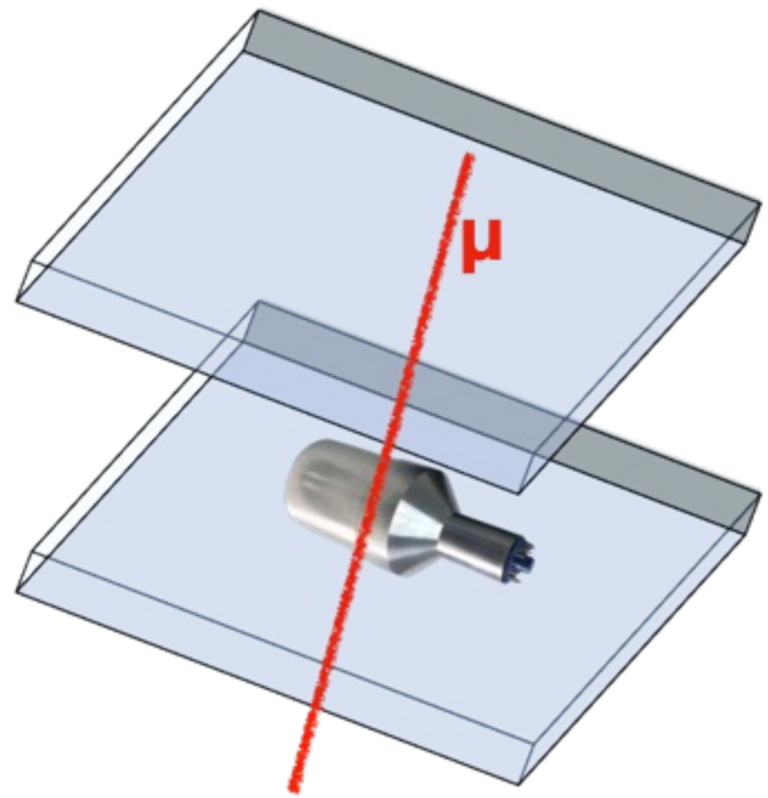
- Ion detectors need identified in multiple Cat A experiments
  - Energies up to 20 MeV, large areas: need to be custom constructed
  - Particle ID desired → ΔE/E detector and/or pulse shape analysis
  - Calibration: Michigan Ion Beam Laboratory / TAMU?
  - Operation up to several hundred ºC: SiC (significant R&D needed, potentially with TTU Cat B + external collaborators)



Muon Veto and Large-Area Neutron Detectors

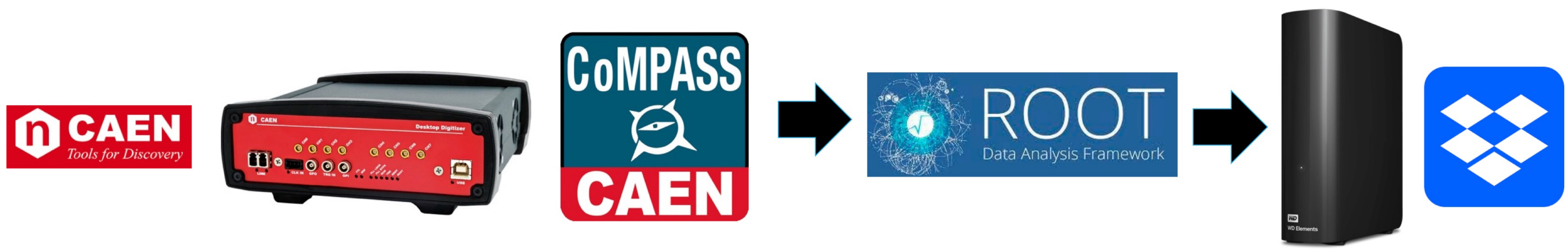
- Reduce backgrounds: veto muons and a fraction of muon-induced fast neutrons
- Increase neutron detection efficiency: custom large-volume liquid or plastic scintillators
- Will be custom-constructed based on needs identified in Cat A experiments

Background monitoring and suppression



Data Acquisition

- Fully digital data acquisition (DAQ)
- Portable CAEN desktop digitizers (8–16 channels): DT5730/40/70
- VME crate 32-channel digitizer if needed
- Data recorded with CAEN CoMPASS: Multiparametric DAQ Software for Physics Applications
- ROOT format: timestamp, waveform or reduced data (energy, pulse shape)
- Data stored locally and on cloud; provided to Cat A teams in accordance with the Technical Data Sharing Plan



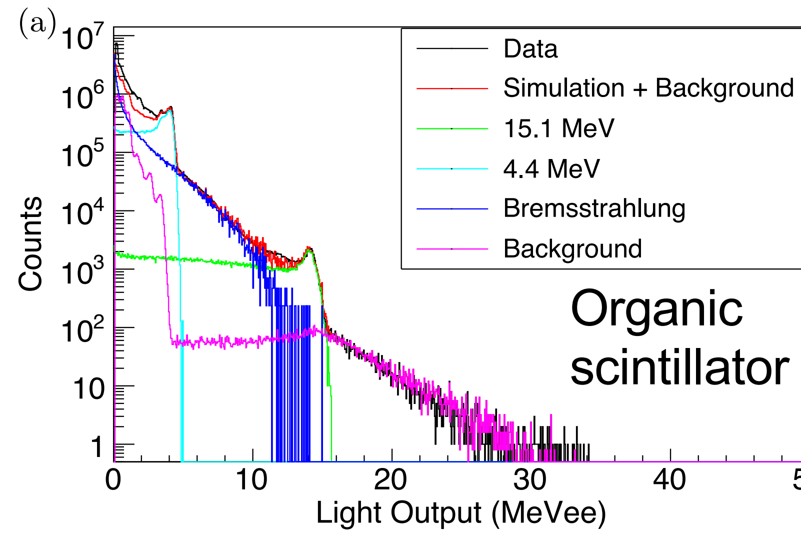
Background monitoring and modeling

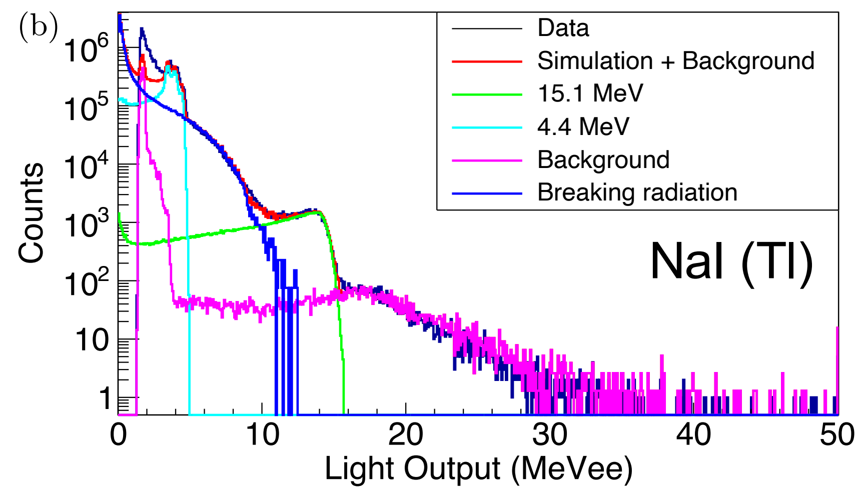
- Use multiple detectors and make long measurements (~1 week) with timestamps
- Continuously record environmental parameters (temperature, humidity, pressure)
- Regular self-calibration with environmental radioactivity and muons
- Simulation of muon background; accounting for diurnal variation
- Measure background during experiments with detectors deployed at various distances
- Consistency check of environmental background using shielding with known characteristics
- Review raw data (waveforms) for anomalies (*e.g.*, signal reflections, EM interference)

Modeling

- Forward modeling of detector signal
  - attenuation in the experimental apparatus
  - effect of detector geometry on signal
  - scintillation quenching for high-LET radiation
  - nonlinearity
  - escape of secondary particles
  - response to surrounding materials (scattering)

- Modeling frameworks: Geant4, MCNP, Fluka





J. Nattress, I. Jovanovic et al., Phys. Rev. Appl. 14, 034043 (2020)

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Data Analysis and Statistical Inference

- Data analysis
  - fully digital data analysis in ROOT framework
  - pulse shape, pileup, charge / light output
  - fiducial cuts for particle ID and pileup rejection
  - time correlations of multiple detectors and external trigger
  - correction for detector drift
  - separate characterization of background
- Statistical inference
  - signal-to-background ratio over various spectral regions
  - ISO 11922 standard → expands upon Currie minimum detectable activity: signal is present vs signal is not present for various C.L. (2σ, 3σ, …)
  - goodness fit to Cat A models: $\chi^{(2)}$/ndf

Initial Test Plan

- **Technical engagement with Cat A teams and the TTU Cat B team**
- **Quick assistance to Cat A teams**
- **Establish Technical Data Agreement**
- Finalize schedule and protocols
- Model radiation transport in experiments
- Design custom detectors and order materials
- Model detector response
- Test custom detectors
- Perform measurements and modeling
- Analyze data
- Publish